

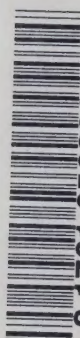
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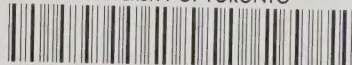
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# IMPLICATIONS OF GLOBAL CHANGE FOR HUMAN HEALTH

*Final Report of the Health  
Issues Panel of the Canadian  
Global Change Program*

CANADIAN  
GLOBAL  
CHANGE  
PROGRAM



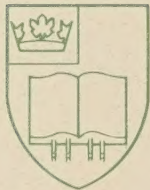
PROGRAMME  
CANADIEN DES  
CHANGEMENTS  
À L'ÉCHELLE  
DU GLOBE





Founded in 1985, under the auspices of the Royal Society of Canada, the CANADIAN GLOBAL CHANGE PROGRAM brings together scientists and other specialists from many disciplines in the sciences and humanities to plan interdisciplinary research, assess the significance of this research in the policy context and communicate the implications to its target audiences. The Canadian Global Change Program is characterized by its independent, non-governmental status, its combination of the natural and human dimensions of global change, its access to worldwide networks of collaborating organizations, its emphasis on issues that have universal relevance throughout the globe, and its access to Canadian capability that can be brought to bear on these issues.

Créé en 1985 sous les auspices de la Société royale du Canada, le PROGRAMME CANADIEN DES CHANGEMENTS À L'ÉCHELLE DU GLOBE regroupe des scientifiques et des spécialistes de nombreuses disciplines des sciences exactes et humaines dans le but de planifier la recherche pluridisciplinaire, d'évaluer l'importance de celle-ci dans le contexte des politiques en place et de faire connaître ses répercussions à ses groupes cibles. Le Programme canadien des changements à l'échelle du globe se caractérise par son statut d'organisme non gouvernemental indépendant, par le fait qu'il s'intéresse à la combinaison des dimensions naturelles et humaines des changements de portée planétaire, par son rattachement à des réseaux mondiaux d'organismes qui collaborent entre eux, par l'accent qu'il place sur les questions qui, dans le monde entier, ont une portée universelle et par le fait qu'il a accès à des compétences canadiennes pouvant être consacrées à la résolution de ces questions.



THE ROYAL SOCIETY OF CANADA is an independent, non-profit organization that was incorporated by an act of Parliament in 1883. Its primary objective is to promote learning and research in the arts, letters and sciences in Canada. It draws on the knowledge and expertise of its Fellows to recognize and honour distinguished accomplishments, to promote public understanding of scholarly, scientific, technical and cultural issues, and to foster the free circulation of ideas through international exchanges and participation in scientific and cultural programs.

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# *Implications of Global Change for Human Health*

---

## ***Final Report of the Health Issues Panel of the Canadian Global Change Program***

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*This publication has been reviewed by the Research/Policy Committee of the Canadian Global Change Program. The opinions expressed are those of the authors and not necessarily those of the Royal Society of Canada.*





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*The following members of the Canadian Global Change Program's Health Panel are the authors of this document. The Canadian Global Change Program would like to thank them for the generous amounts of time and energy they voluntarily gave to the Program and the issues.*

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## Executive Summary

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Canada is the second largest land mass in the world, making research on human health and global environmental change particularly relevant here. However there is no comprehensive approach to health aspects of global change in Canada.

The Health Issues Panel of the Canadian Global Change Program examined the implications of global change for human health. The aims were to identify and prioritize research themes in the health sciences related to global change, provide guidance for research funding and provide input to the policy sector on health implications of global change.

The Panel reviewed the health implications of global warming, stratospheric ozone depletion and ultraviolet irradiation; environmental pollutants (acid precipitation and heavy metal contamination); and unchecked population growth.

We discuss managing risks, the role of human values and ethics in shaping our views of the world and the public health role in sustainable development. Sustainable development involves establishing an economic structure that consumes only as much as the natural environment produces and emits only as much as the natural environment can absorb. It can be accomplished through reduced consumption, reduced economic development, recycling and reuse. This will require a restructuring of society. The adverse impacts on health of global change are, indeed, so serious that we must make these changes in society.

We developed a framework for health-related global change research in Canada. The framework consists of four categories, three based on threats to human health from different types of global change and a fourth recognizing the importance of human behavioral responses to global change. The first three categories are: threats to human health from industrial and agricultural pollution; from changes in the global environment; and from current and future patterns of population growth and levels of consumption. The fourth category is health-related human behavioral responses to global change.

The Panel surveyed leading health researchers and policy makers in Canada in order to identify priorities for health-related global change research. Two questionnaires were circulated to approximately two hundred institutions and individuals, the first seeking opinions on priorities for research and the second on barriers to implementation of interdisciplinary programs in global change. The results are discussed in the report and reflected in the recommendations.

We found wide agreement on the nature and importance of health problems caused by global change. Much of the research expertise is already available in Canada. It is hoped that the Research Councils will recognize the high priority of global change research related to human health and encour-

age research proposals in this area. We would also like to see the establishment of at least one national centre of excellence dedicated to health-related global change research.

A Canadian program in health-related aspects of global change should give priority to relevant Canadian features. We identified areas in which Canada could play a leading role internationally. Areas for improvement were also identified, including the need for development of longitudinal data bases, and the development of links and interdisciplinary thinking between the social sciences, natural sciences and health sciences.

The Health Issues Panel recommends that:

1. Efforts should be undertaken to ensure that all members of the biomedical science community and all practicing health professionals in clinical and public health practice are made aware of the importance of health issues associated with global environmental changes and of the actions needed to minimize the impact of global change.
2. Governments in Canada and other developed countries should allocate a proportion of their health budgets to knowledge development and transfer for the prevention of diseases and health promotion, especially aspects related to global change.
3. Canada should take a lead role in facilitating the development and conduct of a long term international cooperative health research program related to global change.
4. Canada should develop model structures that can be used as prototypes for the conduct of multidisciplinary long term research related to global change.
5. The Canadian health research community should communicate to decision-makers the importance of global change issues to the future health of Canadians and the world.
6. Canada should foster communication between health researchers on global health issues in Canada and internationally.
7. Canada should establish surveillance systems to assess trends in population exposures and disease risks related to global change.
8. A National Centre of Excellence for multidisciplinary studies of the health impacts of global change, ways to ameliorate the adverse effects of global change, and ways to minimize the adverse affects of unavoidable global change should be established by the Research Councils, in collaboration with Federal and Provincial governments.



In addition we recommend specific research priorities in each of the four categories of the framework on threats to health arising from:

9. Industrial/agricultural pollution: Priorities include improved disease surveillance systems and risk assessment of the effects of global air pollution on susceptible groups; research into the role of chronic exposure to toxic contaminants in drinking water; and methods of providing more effective waste management and water treatment.
10. Changes in the global environment: Priorities include research into the use of scientific information in political decision making; agricultural research on heat and drought resistant crops, pest control and food storage under adverse conditions; surveillance systems to monitor ground-level ultraviolet radiation, atmospheric ozone levels and skin cancer and cataract incidence rates; and epidemiologic research to assess the efficacy of sun-screens and other preventive regimens against skin cancer.
11. Consumption patterns: Highest priority should be for research on contraception for men and women as well as making existing contraceptions widely available. Other priorities are research on groundwater conservation and on the relation between human health and biodiversity.
12. Human behavioral responses to global change: Priorities should include broadly based research on human values and the environment, research into methods of

mitigating the social dislocation of severe global change and research on health education and independence for women.

Further recommendations address the issues of public health policy and action.

13. Public health action should include advisory messages about sun exposure, standard-setting and advice on protective clothing and health education directed at behaviour change.
14. There is an important advocacy role for health workers in advising national leaders to take action to limit the burden of greenhouse gases.
15. Public health should play an active role in health promotion, disease prevention and health care of migrant populations.
16. As violent weather disturbances are more and more recognized as a feature of global change, mass movement of refugees from environmental disasters may occur. Disaster preparedness is an important part of planning for global change.
17. The development of national food and nutrition policies in keeping with sustainable development and with the ability to respond to major disruptions that are likely to be associated with global change requires input from public health at the policy level.



## Preface

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In January 1992, the Canadian Global Change Program of the Royal Society of Canada established a Panel on Health Issues related to global environmental changes. The terms of reference for the Panel included the following elements:

- 1) To review the current state of knowledge about health effects of global change with particular reference to Canada.
- 2) To identify gaps in knowledge, key information and communication.
- 3) To set priorities for research aimed at closing gaps, and make recommendations to Canadian Health research funding agencies.
- 4) To establish and maintain networks of research workers on aspects of global change with implications for health, both within Canada and elsewhere.
- 5) To produce reports for distribution to the CGCP Research Committee and other specialized research committees and panels of the CGCP.
- 6) To prepare a document for general distribution on the health implications of global change for Canadians.

As for all CGCP's Panels, the goal was not to undertake new research but to come to a reasoned judgement, based on the existing literature and on the knowledge of the health community, about the likely implications of global ecological change for human health. Panel members were chosen to

represent a broad spectrum of the health research community in Canada.

Panel members first met in January 1992 to discuss the terms of reference, goals and objectives. It was then agreed that the emphasis of the Panel's work was to be on defining research priorities although all agreed that policy issues were extremely important. A framework for health related Global Change Research was then prepared and circulated to research workers, health science faculty deans and research directors, chief executive officers of research councils, and other key individuals. This survey showed a high degree of agreement among respondents. A second round for this Delphi-like survey took place in September 1993. A preliminary Table of Contents was then produced and Panel members were assigned various sections of the report. An independent consultant was hired to assemble and integrate all the material in a draft version that was circulated for final comments and revisions.

Over the period of a little more than two years of the panel's existence, panel members met on a number of occasions as well as exchanging comments by mail and telephone. In addition, in June 1993, representatives of the Research Councils, of the International Development Research Centre and of the Health Protection Branch of Health and Welfare Canada met the Panel members to discuss research priorities and funding problems. These activities, combined with the results of the surveys formed the basis for this report and for the recommendations it contains.





## Chapter 1

### Introduction

In April, 1993, the Union of Concerned Scientists, made up of a majority of Nobel laureates in physiology, medicine and the sciences as well as over 1500 other internationally recognized scholars, issued a *Warning to Humanity* (Union of Concerned Scientists, 1993). This stated that humans and the natural world are on a collision course: humans are inflicting harsh and often irreversible damage on the environment and on critical resources. If nothing is done to stop this, there will be dire consequences for our world as we know it. The Warning explained the dangers to the environment — to the atmosphere, water resources, oceans, soil, forests and living species. It pointed out the dangers of unrestrained population growth. It called for a rapid end to environmentally damaging activities and urged sane resource management and population stability. It also noted that broad social changes would be necessary, in particular the worldwide elimination of economic and social inequalities. In line with these concerns, the Health Issues Panel was given the mandate to respond to and provide advice to the Canadian Global Change Program on the human health implications of global change.

What is global change and what causes it? The numerous interacting sub-systems which constitute the global ecosystem exist in a state of dynamic balance that is slowly changing at a rate consistent with the geologic time scale. Today, human activity is altering entire global systems such as the atmosphere and the oceans at an unprecedented rate. Global change results “when large global and regional systems are altered at a rate that is much faster than those systems are accustomed to experiencing.” (Canadian Global Change Program, 1993). Global change research examines not only the consequences of such rapid change and how global (climate, atmosphere, oceans) and regional (tropical rainforests, coastal areas, lakes, deserts) systems will adjust to such changes, but also how societies and economies will be affected by these changes — as well as how they will attempt to adopt and mitigate them.

The rapid alterations of global change include sudden catastrophic natural events such as volcanic eruptions or meteorite impacts. But today the major impact of global change is coming from increasing consumption of resources by the world's rapidly expanding population, accompanied by the creation of unwanted by-products. Thus the energy we use to heat and to light, to cook and to transport, derives from fossil fuel combustion, releasing toxic gases into the atmosphere, resulting in acid rain and polluted air. Technological innovations such as modern farming practices have boosted productivity but not without a price: nutrients are now being drawn out of the soil faster than they can be replaced, and fertilizers are leaching into the environment and affecting fish, birds and insects. Stratospheric ozone depletion results from the use of certain chemicals. Global change thus arises from the combined forces of exponential population growth, energy and resource con-

sumption, global economic forces such as debt repayment and unequal wealth distribution, technology and culture and values.

The world's population is increasing exponentially and it is expected to pass six billion by 1998, and 10 billion by 2030. With modern methods of transportation, open borders, and factory farming large numbers of people are leaving rural areas for urban centres and developing countries for developed countries. But in the quest for speed, efficiency and economic security, damage to the environment is not considered. Urban smog from automobile fumes, toxic spills and carelessly discarded medical waste are a few examples of serious problems which result. While some concerns are regional, many are international, and may affect the entire planet.

Research issues concerning human health and global change are particularly relevant to Canada, both in terms of the potential impact on the Canadian environment and economy and in terms of Canada's contribution to the problem. Canada is the second largest land mass in the world and contains the environmentally and culturally sensitive Arctic permafrost region, much of which would become a swampy wasteland if global temperatures were to rise. Canada contains a large portion of the world's fresh water, has one of the world's longest coast lines and has several large metropolitan areas at, or near, sea level. As one of the world's most industrialized countries, Canada has one of the highest levels of per capita resource consumption, including health resources. Unfortunately, it is also one of the world's highest per capita emitters of atmospheric air pollutants. Pollution has already begun to affect the health of animals and humans in the Arctic. Global changes would put Canada's economy and health care system under increasing stress. Because Canada is so vast yet so sparsely populated, it is an inviting choice for immigration. Many of our immigrants come from areas where global change has already affected their lives directly.

Although there is some important research being done here, there is no coordinating body to link disciplines, to monitor the work being done or to allocate funds for research equitably. The aims of the Health Issues Panel were to identify and prioritize important research themes in the health sciences related to global change to provide guidance for research funding and to bring to the policy sector an awareness of the health implications of global change. We conducted a brief review of the literature on the health effects of global climate change and issues related to sustainable development. We developed a framework for considering threats to health arising from global change and circulated this to biomedical and clinical research workers and administrators of research. These consultations were used to set priorities for research and to find ways of facilitating global change research in Canada. This document reports on these findings and concludes with recommendations.



## Chapter 2

### Health Effects of Global Change

Global environmental change has direct and indirect implications for human health. Many scientific articles and monographs have described these aspects of global change and advocated action. Articles in medical journals have described the implications of global change for human health and discussed medical responses (Last, J.M., 1993). Recent books (Chivian, 1993; McMichael, 1993) have provided comprehensive reviews of knowledge and contain plans of action at international, national, local and personal levels. UN agencies, including the United Nations Environmental Programme (UNEP, 1991), the World Bank (World Bank, 1992), the World Meteorological Organization (WMO, 1991) and the World Health Organization (WHO, 1992), have produced state-of-the-art reports. International Council of Scientific Unions (ICSU) Reports (ICSU, 1990, 1992) have recorded the changes. The Intergovernmental Panel on Climate Change (IPCC) has published important summaries of the situation (IPCC Group 1, 1990; IPCC Group 2, 1990). Government-sponsored reports on aspects of global change have been published in Australia (National Health and Medical Research Council, 1991), the Netherlands (Dutch National..., 1988-89), the U.K. (The Global Climate Observing System, 1991) and other countries. The World Health Organization report, *Our Planet, Our Health* (WHO, 1992) described and discussed existing knowledge and offered recommendations to improve the situation. Under the heading of "Health and Climate Change" the British journal, *Lancet*, published an important series of articles summarizing current knowledge about the basic science of climate change (Maskell, 1993), biodiversity (Dobson, 1993), stratospheric ozone depletion (Lloyd, S.A., 1993; Jeevan, A., 1993), marine ecosystems (Epstein, P.R., 1993), vector-borne diseases (Freier, J.E., 1993; Rogers, D.J., 1993; Nicholls, N., 1993; Shope, R., 1991), food supply (Parry, M.L., 1993), impact on cities (Kalkstein, L.S., 1993) and critical regions (Almendares, J., 1993), and necessary monitoring procedures (Haines, A., 1993).

In Canada, aspects of global change and related health problems have been described and discussed in several reports sponsored by government departments including the Environmental Health Directorate of Health and Welfare Canada (Env. Health Directorate, 1991; Health and Welfare Canada, 1992), the Canadian Climate Centre (1993), Environment Canada (Env. Canada, 1991) and the Laboratory Centre for Disease Control (1992). A report from IDRC (1992) considered the impact of global change on the developing world from the perspective of the Canadian Official Development Assistance program. A report that related ecosystem health to human health was produced by a Task Force of the Canadian Public Health Association (1992).

The Health Issues Panel concentrated on four main areas of impact of global change on human health: global warming,

ozone depletion and ultraviolet radiation, environmental pollution and population pressures and movements. The aim was not a comprehensive review, which has already been undertaken in many of the above reports, but rather a starting point for the consideration of research priorities in Canada.

#### Global Warming

The implications of a greenhouse effect enhanced by humans have been of theoretical interest for decades, appearing in the 1960s as a distant threat (Daily, G.C., 1990). Since the mid 1980s implications of global warming have aroused considerable concern.

The greenhouse effect is a natural process which stabilizes the world's temperature by preventing the escape of radiant heat into space. Atmospheric carbon dioxide (CO<sub>2</sub>) is the chief greenhouse gas influencing climate. For the past 10,000 years, the concentration of CO<sub>2</sub> remained fairly constant until about 150 years ago. Due to the increasing population and the changes caused by industrialization and agriculture, concentrations of carbon dioxide (and the other greenhouse gases) have been increasing in the atmosphere, enhancing the natural greenhouse effect. One predicted scenario is that global temperature could rise an average of 2°C in the next 50 years.

According to most of the theoretical models of future climate, the rise in average temperature is likely to be less at the equator and greater at higher latitudes; most models suggest significant seasonal warming in polar areas as well as in the interior regions of Asia and North America. On average, over the next 50-100 years, there could be up to a 6-8°C temperature rise in mid-latitude zones. The range from low to high could be wider because of disruption of stabilizing forces in winds and ocean currents. It is also believed that global warming will result in an increase of extreme weather events.

Unlike previous periods of rapid change, humanity is now dependent on an intricate system of agriculture, trade and communications that is threatened with disruption. Global warming will affect all aspects of human life: local, regional and global ecosystems; forestry and agriculture; water supplies; sea level and ocean currents; fisheries; industry and transport; urban planning; demographics and human health. There are potential economic and political consequences and security implications.

#### Weather

Global warming could disrupt ocean currents and establish anomalous air flows, associated with trade winds and jet streams. Besides causing more prolonged droughts in some regions, other regions, such as the tropics, may experience more



severe precipitation. This could result in an increase in the severity of violent weather disturbances such as hurricanes, tornadoes, severe rainstorms, floods and blizzards.

Such natural disasters have many public health consequences. Sewage treatment and water purification plants can be incapacitated, large numbers of people may be temporarily or permanently rendered homeless; emergency services may be unable to cope. If the disaster is widespread, emergency measures and disaster relief on an adequate scale may be impracticable. Increased frequency of such disasters could seriously threaten economic stability and the maintenance of many essential forms of infrastructure, including public health services.

### *Heat Effects*

Global warming will have at least one direct health effect: an increase in heat-related illness. Many temperate zone cities, including Toronto and Montreal, can expect to experience a doubling of the average annual number of very hot days, with more and longer heat waves. These heat waves would impose a severe strain on many essential services, including fire departments and ambulances. The heat alone aggravates existing medical problems, particularly for the old, the young, the chronically ill and those who must work outdoors. There is clinical and epidemiologic evidence that ambient temperature affects daily variation in mortality in urban populations more than pollution levels do. This effect on mortality is diffuse, affecting all causes of death, not just respiratory and cardiovascular system deaths.

Acclimatization to increasing temperatures occurs gradually, particularly among older people, and may be slower than the rate of temperature change. Higher ambient temperatures are associated with higher body core temperatures. Higher body core temperatures have been linked to elevated perinatal deaths and pre-term births. Both peak in the summer and may increase during an acclimatization phase of a population to higher temperatures. An increased incidence of renal calculi (kidney stones) is also associated with higher environmental temperatures and the accompanying sweating that leads to greater dehydration.

Prolonged heat waves also cause deaths from heat stroke and other heat-related illnesses. During a severe heat wave in the US mid-west in 1980, about one in every four thousand residents developed heat stroke and one in fourteen hundred had a heat-related illness that led to hospitalization or death (Kalkstein, L.S., 1993). Heat waves are also associated with outbreaks of violent and other antisocial behaviour. These might increase in frequency during times of economic chaos and sociodemographic transformation, which might be expected to accompany climate change. Air conditioning reduces heat related morbidity but has an impact on carbon and CFC emissions, and urban air pollution increases heat-related morbidity and mortality (Kalkstein, L.S., 1993). In the crowded cities and periurban slums of many developing nations, air pollution is a serious problem and there is no air conditioning.

### *Sea Level*

Global warming is expected to cause a rise in sea level of about 0.5 m over the next 50 years due to thermal expansion of seawater and melting of polar and alpine ice-caps. Since a large number, perhaps 500 million, of the world's people live at or very near sea level, significant sea level rise will create millions of environmental refugees, particularly in Southeast Asia. A sea level rise will also inundate coastal wetlands and disrupt the complex ecosystems that sustain many of the world's richest fisheries. Many estuarine freshwater supplies will become undrinkably saline. Sea level rise threatens entire regions of nations such as Bangladesh, the Maldives and The Netherlands. Salt water intrusion into coastal aquifers may compromise the fresh water supply of coastal cities and may seriously damage or incapacitate sewage and sanitation systems causing increases in fecal-oral infections. Low-lying cities, particularly on river deltas, will be at risk of flooding. The rise in sea level would threaten Canada's coastal cities, including Saint John, Vancouver and Charlottetown. Secondary effects could occur in the St. Lawrence River estuary.

In much of the interior of North America, fresh water supplies may also be threatened. Groundwater, especially fossil water, is being used at a much faster rate than natural replenishment. The increasing demands on this water and the absence of adequate precipitation to recharge these aquifers will further exacerbate water shortages.

### *Infectious Diseases*

Another consequence of a rise in average ambient temperature will be the greater abundance and wider range of insect vectors of disease. Temperate zones will become more hospitable to some important insect vectors, notably anophelene and culicine mosquitoes, and to the pathogens that they carry (Shope, R., 1991; Cook, G.C., 1992). Malaria parasites and arboviruses, such as those responsible for viral encephalitides, dengue and yellow fever, will have more vigorous life cycles and may become more virulent. Schistosomiasis could become established if snail intermediate hosts are present and human hosts disregard sanitary measures. This could occur with changing agricultural and water use patterns — for example, if immigrants carrying the parasite settle in areas with more damming to improve water availability in arid regions. Other water-borne diseases which might become more prevalent include Ross River fever, cholera and other fecal-oral infections. The risks will be influenced by changes in rainfall and salinity.

Phytoplankton and blue-green algae in surface layers of the oceans can form a symbiotic relationship to *Vibrio cholerae* (Epstein, P.R., 1993), raising the risk of endemic and epidemic cholera in certain localities (e.g. coastal water around parts of Central and South America). Although this is not an immediate threat to health in Canadian coastal waters, the phenomenon illustrates one of many complex interactions that could lead to dramatic changes in the risk of epidemic disease associated with new or emerging pathogens.



Probably of greatest significance will be an increase in water- and food-borne diseases causing diarrhea. This is the leading cause of early death in the developing world. Although there may not be the same impact in Canada due to a better public health system (despite the lower immunity), some inner-city areas could be affected. It is also important to consider that many of the disease-inducing organisms are developing resistance to antibiotics.

Diseases now limited to the tropics will probably extend over a wider range, invading what are now temperate zones. Vectors now limited by climate but transportable in ships, trains, planes and cargo could become established beyond their present range. The result could be the establishment of previously alien vectors, followed by the introduction of diseases formerly unknown in the area (Shope, R., 1991). Examples include arthropod-borne viral diseases, such as viral haemorrhagic fevers (yellow fever, dengue) and viral encephalitides; tick-borne diseases, such as typhus and Lyme disease; malaria and perhaps bubonic plague. Some mosquito-borne arboviral diseases that now occur sporadically in Canada, such as St. Louis encephalitis, may extend their seasonal and geographic range. Lyme disease may become a bigger problem. This is a special case, because its current increased incidence is probably due in part to extinction of predators that formerly limited the range and number of deer, the natural host of this tick-borne borrelial infection. Eastern equine encephalomyelitis may pose the biggest danger, because it attacks not only humans but also

important domestic animal herds (Freier, J.E., 1993). We have effective vaccines and other preventive measures against some of these diseases, but not against others (see Table 1). It is also important to consider the likely impact of the migrated vectors on our food crops and livestock.

Pesticide spraying to control newly introduced vectors would carry additional unattractive ecological and health consequences as well as increasing the prevalence of pesticide-resistant vectors.

### *Food Security*

Food security will become an important issue over much of the world if global warming leads to severe food shortages and ultimately famines. The effects of warmer climate and increased atmospheric CO<sub>2</sub> vary with different crops and changes in precipitation. Although increased concentrations of carbon dioxide may increase yields for some crops, increased temperatures and aridity are expected to cancel these effects. Several alternative scenarios have been modelled by Goddard Institute of Space Studies, Geophysical Fluid Dynamics Laboratory and U.K. Meteorological Office (Maskell, K., 1993). All scenarios agree that food production is likely to decline as the climate gets warmer. The expected decline in soil moisture could seriously impair grain production. Areas now devoted to grain production will become more arid with significant loss of topsoil during dust storms. Widely swinging temperatures and unpre-

**Table 1. Currently available vaccines**

|                                                 |                                                                                                                                                                                   |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Currently used in childhood, or could be</b> | Diphtheria-pertussis-tetanus (DPT)<br>Polio<br>Measles-mumps-rubella(MMR)<br>Haemophilus influenzae<br>Hepatitis A<br>Hepatitis B<br>Varicella                                    |
| <b>Sometimes used now</b>                       | Tuberculosis (BCG)<br>Polyvalent pneumococcal vaccine<br>Rabies                                                                                                                   |
| <b>Used by travellers, high risk groups</b>     | Typhoid<br>Influenza virus vaccine<br>Para-influenza<br>Plague<br>Yellow fever virus vaccine<br>Polyvalent meningococcal vaccine<br>Cholera<br>Japanese encephalitis<br>Tularemia |
| <b>Currently being tested</b>                   | Malaria<br>Scrub typhus                                                                                                                                                           |



dictable rainfall patterns will make many grain yields uncertain. Even if Canada is less adversely affected by reduced grain production than other countries, the effects will be felt through immigration of large numbers of ecological refugees, forced to move by catastrophic decline in food production elsewhere in the world.

Food crops will be affected in various other ways. Changes in distribution of pests may have a significant impact on fruit and grain production. While migration of crops to new, better-suited zones may be possible in some instances, other conditions may prevent this: northward migration of wheat cultivation might be limited by soil conditions.

With migration of plant species will come exposure to new or greater concentrations of allergens — especially pollen — in some areas, leading to increased incidence of asthma. Asthma is already a rapidly increasing cause of death among young people (doubling approximately every five years). The causes for this increase are poorly understood.

### *Migration and Health*

Canada has been a destination for immigrants and a haven for refugees for many years. Recently, immigration patterns have changed and we are seeing more environmental refugees. They are coming from countries experiencing the stresses of overpopulation, inappropriate agricultural methods, and conflicts precipitated by environmental stress (Homer-Dixon, T.F., 1991). Disease patterns among migrants often differ from those among the resident population. Migrants often carry health problems from their place of origin and may be vulnerable to new diseases at their destination. Exotic diseases are more likely among immigrants from tropical Africa, Haiti, and South and South-east Asia (Cousineau, D., 1991). Some diseases that are prevalent among immigrants (e.g. tuberculosis) can be transmitted easily to people already resident here. Immigrants are less likely to be adequately screened and treated for serious disease occurring when arriving or after their arrival in Canada (Anderson, G.H., 1992) and less likely to avail themselves of primary prevention services. With the focus on infectious diseases, little attention is paid to identifying and modifying health-risk behaviours of immigrants. Increasing numbers of ecological refugees will require us to have a greater understanding of their special health needs.

### **Stratospheric Ozone Depletion and Ultraviolet Irradiation**

All that lies between life on earth and the damaging ultraviolet (UV) rays of the sun is a layer of ozone, which, if condensed to sea-level pressure and room temperature, would be only 3 mm thick. The stratospheric ozone layer is situated at an altitude of 12-45 km, the ozone only being present in trace amounts. The ozone is produced by the action of ionizing and UV radiation on oxygen, and protects the earth from what would otherwise be levels of UV radiation sufficient to kill many forms

of life. The ozone layer completely absorbs UV-C rays (wavelengths <280 nm) and partially absorbs UV-B rays (280-320 nm), although it does not absorb the least damaging rays, UV-A (320-400 nm).

In 1976, Rowland and Molina (Rowland, F.S., 1976) showed that halocarbons such as chlorofluorocarbons (CFCs) destroyed ozone by producing chlorine monoxide. A single molecule of chlorine monoxide can destroy many thousands of molecules of ozone. CFCs were then being released into the atmosphere in large quantities, from propellant spray cans, refrigerants, cleaning agents for electronic circuitry and styrofoam insulation. Rowland and Molina predicted that unless the release of CFCs was curtailed, the stratospheric ozone layer would be seriously damaged. These theoretical conclusions have been confirmed by empirical observations. Since the late 1970s, the average density of the stratospheric ozone layer has declined by about 3%, with some regions experiencing much greater declines. In 1985, Farman and colleagues first observed serious attenuation (the so-called "hole") in the stratospheric ozone layer in Antarctica (Farman, J.C., 1985). This seasonal depletion of the ozone layer has been monitored closely ever since. It is greatest in late winter and early spring, and has become more extensive each year. Since 1989 it has extended into southern Australia and the lower third or so of Chile and Argentina. In 1992, NASA high altitude observations over northeastern U.S.A. and eastern Canada revealed very high concentrations of halocarbons in the upper troposphere and lower stratosphere. This was followed in the late winter and early spring of 1993 by 20% decline in ozone levels measured over Toronto, accompanied by an increase in surface levels of UV-B radiation (Kerr, J.B., 1993). These observations were the first in the world to show such a striking correlation. The northern hemisphere ozone depletion occurred again in the late winter and early spring of 1994, although it was somewhat less severe. It is difficult to predict future trends in ozone depletion. There is controversy about the rate at which the ozone layer is "repaired" by natural forces. There is a broad consensus that the depletion will persist for 100 years.

These levels of decline in the ozone layer are particularly alarming when one realizes that at larger ozone losses, skin cancer rates may increase exponentially. Whereas for ozone depletions of less than 5%, each 1% decrease in ozone leads to a 2% increase in non-melanoma skin cancer, a 10% decline leads to a 24% increase, a 30% loss to 100% increase and a 50% loss to a 400% increase (Kripke, M.L., 1990). This occurs partly because of the parallel absorption spectra of ozone and DNA. Ozone absorbs UV-B wavelength for wavelength in the same spectrum as DNA absorbs UV-B, thus shielding biological matter from the harmful effects of UV-B.

The biological and human health effects of UV radiation are summarized in Table 2.

The public health consequences of depleted stratospheric ozone are rather easily projected. Intracellularly, UV-A is absorbed by proteins and DNA, UV-B by all nucleic and aromatic acids,



**Table 2. Effects of UV radiation**

|                                 |                                                                                                               |
|---------------------------------|---------------------------------------------------------------------------------------------------------------|
| <b>Biological Effects</b>       |                                                                                                               |
| <b>Ecologically important</b>   | Impaired photosynthesis<br>Impaired plant growth<br>Impaired motility of phytoplankton                        |
| <b>Agriculturally important</b> | Impaired reproductive capacity<br>Damage to nitrogen-fixing soil bacteria<br>Impaired plant and animal health |
| <b>Human Health Effects</b>     |                                                                                                               |
| <b>Immunosuppression</b>        | Enhanced susceptibility to infection<br>Cancer proneness                                                      |
| <b>Dermatological</b>           | Sunburn<br>Loss of skin elasticity (premature aging)<br>Photosensitivity                                      |
| <b>Neoplasia</b>                | Malignant melanoma<br>Squamous and basal cell cancer<br>Cancer of the lip                                     |
| <b>Ocular</b>                   | Cataract<br>Pterygium                                                                                         |

and UV-C by all cellular constituents. Absorption of UV radiation leads to breakage of covalent bonds in critical macromolecules and to carcinogenesis, accelerated aging and cataracts. UV-B radiation impairs the function of dermal Langerhans cells and induces suppressor T lymphocytes. Thus the health effects of increased UV radiation include: 1) higher risk of non-melanoma skin cancer (particularly squamous cell carcinoma and actinic keratitis, a premalignant condition) (Vitas, B.C., 1990; Moan, J., 1989; Pitcher, H.M., 1990); 2) malignant melanoma (Pitcher, H.M., 1990); 3) cataract and retinal degeneration (Charman, W.N., 1990); and, 4) impaired immunological responses (Jeavan, A., 1993) that reduce resistance to infection and increase the risk of systemic malignancies (Kripke, M.L., 1989). Relatively minor, but cosmetically significant effects include accelerated aging of the skin and increased frequency of pterygia, small triangular tissue webs on the whites of the eye. Although not serious health problems, these cosmetic effects may be significant in motivating action to reduce the exposure risk.

Non-melanoma skin cancer (basal cell and squamous cell carcinoma) is the result of cumulative exposure to sunlight and usually affects the face and hands. Basal cell carcinoma has

less than a 1% mortality rate but a very high incidence rate. Even at high latitudes, as in Canada, exposure to sunlight is the principal determining factor for non-melanoma skin cancer. There is an increase in incidence of approximately 2% for basal cell carcinomas and 1.5% for squamous cell carcinomas for every 1% reduction in stratospheric ozone concentration. However, the amplification factor decreases with increasing latitude, putting residents of southern Canada (the bulk of the population) at greater risk. Skin type also influences susceptibility. Those at greatest risk for direct effects of UV exposure on skin are people with fair skin who sunburn easily, including among them many of Celtic origin and persons with freckles and red hair. Persons with certain rare skin conditions (e.g. albinism, ataxia-telangiectasia) are more predisposed to UV-induced injury.

Cancer registries in Canada and in the Pacific North-west of the U.S.A. among other regions in the world, have demonstrated a consistent increase in the incidence of malignant melanoma for many years. Until now, this has probably been due to increased sun exposure rather than to declines in ozone concentration. Case control studies show that episodic acute and severe sunburn is a more important risk factor than prolonged



less acute exposure with tanning. Nevertheless, fair-skinned and red-haired people are at risk even from brief exposure.

Eye damage is also a significant consequence of increased UV exposure. The cornea absorbs almost all UV-C radiation and a portion of UV-B. Corneal diseases resulting from exposure to UV-B include corneal photokeratitis (snow blindness), pterygium and climate droplet keratopathy (Taylor, H.R., 1989). The lens strongly absorbs UV-B, shielding the retina, but leading to cataract formation. Retinal damage only seems to occur in individuals who have had a lens surgically removed. UV exposure is also a risk factor for melanoma of the iris, ciliary body and choroid.

The effects of UV-B on the immune system are not as well defined as the other health effects, but are potentially more important (Jeevan, A., 1993). Animal studies have shown that UV-B induces suppressor T lymphocytes that inhibit the immune response against skin cancer antigens. This may be responsible for some of the increase in skin cancers with increased exposure, but also suggests mechanisms for increases in systemic malignancies. This ability to impair cell-mediated immune responses also suggests that UV exposure could lead to decreased resistance to infectious agents and acceleration of the course of infectious diseases such as AIDS. Potentially another impact may be to diminish the effectiveness of many common vaccines. These effects of UV radiation on the immune system occur regardless of skin type.

Use of protective clothing, sunscreens and eyeglasses may significantly reduce the translation of increased ultraviolet light exposure into adverse health effects, as may changing fashions in sunbathing and outdoor recreation. Measures taken by individuals to protect themselves are, however, likely to be incompletely effective. Commercial sunscreens may be effective against UV-induced sunburn given a high enough rating and suitable exposure periods, but their effectiveness against UV-induced cancer is, as yet, undemonstrated. Other measures, such as dark or reflective clothing, parasols, protective sunglasses and hats may not be readily accepted as permanent fashion statements by society. Increased shade will be more difficult to ensure in deforested rural areas or water-short communities.

The advisory warnings about UV flux and safe exposure times that are now a routine feature of Canadian weather reports are a useful public health measure that may help to reduce the risk of malignant melanoma, and of non-melanoma skin cancer. Including UV readings in weather reports not only serves to advise on health, it may also influence public attitudes and perceptions of environmental risks.

Much remains to be done about the health risks associated with stratospheric ozone attenuation and increased UV radiation. Studies of health effects — notably of the relationships among ozone concentration, UV levels and incidence rates of melanoma and non-melanoma skin cancer, cataract, and immune-deficiency disorders — have high priority. These were speci-

fied in detail in the report of a symposium on UV-related diseases held in Ottawa in March 1992 (Laboratory Centre for Disease Control, 1992).

Substantial progress on curbing CFC generation and release on both a national and international level has been made, first with the Vienna Convention on the Ozone Layer and later with the more stringent Montreal Protocol, although not all nations have agreed to abide by the conditions. However, given the long half-lives of the CFCs (75 years or more), the emissions already released are expected to persist in their ozone-depleting activities well into the 22<sup>nd</sup> century.

## Environmental Pollution

### *Acid Precipitation*

Acid precipitation has serious effects on delicate freshwater ecosystems, marine biota and also on some species of plants and trees. Surveys of soil and water quality have shown increased acidity and possible irreversible changes in metal mobilization in soils. These effects are caused by increased production and airborne transport, often over long distances, of acid emissions (principally sulphates and nitrates) from industrial sources. The result has been extensive changes in small lake biota and vegetation in eastern Canada and the United States.

The effects of acid precipitation are thought to be primarily ecological and indirect rather than toxicologically significant to humans. Evidence from animal experiments, however, suggests lung injury at environmentally relevant concentrations of acidifying agents. Although some adverse human health effects have been demonstrated, the associations are weak and inconsistent, e.g. between acid fog and individuals with reactive airways and between acid haze and certain varieties of cancer. Work by Canadian, American and Italian investigators suggests possible direct effects of industrial exposure to acidifying agents that may have counterparts in environmental exposures to acid precipitates (Franklin, C.A., 1985; Bates, D.V., 1987; Raizenne, M.E., 1989; Soskolne, C.L., 1989; Speizer, F.E., 1989).

Acid precipitation may also adversely affect human health indirectly, with severe consequences, if essential food chains are disrupted. Some authors have speculated that if metals are leached into groundwater at excessive concentrations there may be toxicological implications.

### *Heavy Metals*

Heavy metal contamination, including increasingly widespread distribution of organic mercury compounds, lead and cadmium, may be more serious than contamination by organic chemical compounds, such as PCBs and dioxins, which have generated greater publicity. Mercury enters aquatic ecosystems and is concentrated in food chains that end with fish, marine



mammals and those humans who eat them. Mercury passes across the placenta, so that the developing fetus must be considered in relation to fish consumption by women in their reproductive years.

Although it has numerous adverse health effects, lead has been an issue of little public concern since lead poisoning is rare in Canada. Ambient air concentrations have been falling since 1973, but levels in water and soil are unknown. Canada is the world's third largest producer of mined lead and Canadian consumption is growing. Major lead-using industries include the manufacture of lead-acid batteries, paints and coatings, solders, lead-soldered cans, telephone and power cables, piping, roofing and electrical equipment.

Uptake of lead by humans is through inhalation and ingestion. Lead has numerous health effects at high blood levels, including disturbances in blood cell synthesis, increased blood pressure, effects on the nervous system and reproductive effects such as disturbances of male fertility, spontaneous abortions, premature labour, low birthweight, congenital anomalies and chromosomal effects. Recently, concerns have mounted about the health effects of low levels of lead, which were previously considered normal. Low-level lead exposure during infancy and early childhood has been shown to have adverse effects on neuropsychological development through the first seven years of life (Baghurst, P.A., 1992).

### *PCBs*

Polychlorinated biphenyls (PCBs) are a group of chlorinated aromatic hydrocarbons manufactured commercially by the progressive chlorination of biphenyls. All commercial preparations of PCBs are liquid mixtures of many isomers. The distribution of isomers may change with small amounts of dioxins and furans.

PCBs are very stable compounds and highly persistent in the environment, where they bioconcentrate in the food chain and accumulate in fat tissues. Although production of PCBs in Canada was banned in 1980, their stability and persistence means that they will be environmental pollutants for many years, already being among the most widely distributed synthetic compounds on earth. PCBs are a significant pollutant in the Arctic, where they are a particular hazard because of the native diet.

Human exposure to PCBs is 97% through ingestion, particularly fish and maternal milk. Levels in maternal milk and fat tissue may be 200 times as high as levels in blood. Evidence suggests decreased birth weight and possible behavioral abnormalities in infants born to mothers with relatively high PCB intakes. Evidence of neurotoxicity in the form of abnormal tests of memory and cognitive function has also been reported (Kinloch, D., 1988), although these changes may reverse after detoxification.

Concern about PCBs as a human health hazard is largely related to their known carcinogenicity in animals. A more com-

elling reason for stringent control of the PCBs is their extreme persistence in the environment and the hazard to other species through bioaccumulation. Unrecognized effects on humans cannot be ruled out.

### *Radioactive Waste Disposal*

Radioactive waste disposal from nuclear power stations, weapons production and nuclear powered vessels has become a serious problem worldwide. Of particular concern has been the revelation that the former Soviet Union has been dumping such wastes directly into the Arctic Ocean, into river systems in northern Russia and onto unstable frozen soils. More than a dozen other countries have also at one time or another disposed of radioactive waste in a manner that could seriously threaten the environment. This is a potential environmental calamity of immense international proportions which the world is just beginning to tackle. And it will only get worse until a truly safe long-term storage procedure is agreed upon. In addition to the problem of radioactive waste disposal there is the danger of radioactive contamination from nuclear accidents, such as occurred at Chernobyl.

### *Population Pressures*

Ultimately it is the pressure of population growth that is responsible for many of the environmental disturbances threatening human health. The spectacular reproductive "success" of the human species has been achieved at great cost. We have lost many wilderness areas and are losing many species that have competed against human development for a share of finite resources — space, land, water and nourishment. We have perceived that resources are limitless rather than finite. We have cultivated the attitude that everything on earth has been placed here exclusively for human benefit, ignoring the biological cost of human reproductive success. Value systems associated with the world's three great monotheistic religions, Judaism, Christianity and Islam, all hold that everything on earth is here for the benefit of humans. The Hindu and Buddhist traditions and aboriginal beliefs that respect other forms of life may be more compatible with the realities we now face as the earth's resources show increasing signs of exhaustion. We are beginning to realize, perhaps too late, that we are interdependent with many other living creatures.

Since World War II, some of the basic technologies of industry, agriculture and transportation have been developing incompatibly with natural environmental cycles and processes. The search for more profitable production and marketing has led to lopsided technology, successful at meeting narrowly defined goals, but failing with respect to natural systems. There are numerous examples of recent changes in automotive design, electric power generation, packaging and bottling, manufacturing processes and farming practices, that are self-defeating in the total ecosystem. While recognizing the important role of individual lifestyle and population stabilization, the single most important factor in achieving environmental



reconstruction in developed societies is probably control over technology and its rational use.

The situation is different in less developed nations. Population pressure has played an important role in impeding the achievement of a tolerable quality of life. As the education of women advances, the birth rate drops and population growth rates decline. This is one instance in which collective individual judgement results in a rational and productive direction for society as a whole. One promising avenue for population stabilization, and a necessary concomitant for any successful program, is the reduction of child mortality; but this alone is insufficient. Education of women, and their ability to control their own fertility, are absolutely essential to achieve zero population growth (Davies, A.M., 1992).

## The Next Steps

The facts presented above demonstrate that the situation is serious and it will get worse unless we take action to reverse the trends. Some public health actions, such as avoiding excessive sun exposure, are obvious. But many others are needed. They will require what Albert Einstein called “a new way of thinking”. We can settle for nothing less than a complete transformation of the cherished values of our industrial civilization. The Union of Concerned Scientists expressed it thus:

[We need a new ethic] “... a new attitude towards discharging our responsibility for caring for ourselves and for the earth. We must recognize the earth’s limited capacity to provide for us. We must recognize its fragility. We must no longer allow it to be ravaged. This ethic must motivate a great movement, convincing reluctant leaders and reluctant governments and reluctant peoples themselves to effect the needed changes.” (Union of Concerned Scientists, 1993)

There is growing public concern about the implications for human health as well as for the health of the earth of the changes described in this report. Yet most of us have difficulty applying to ourselves the lessons that are plain for all to see. If our own livelihood is threatened, as is that of timber workers in British Columbia and fishermen in the Maritimes, we find it easy to rationalize that our own actions will not make matters worse. Our political leaders make similar rationalizations to justify environmentally unfriendly decisions such as investing in the development of the Hibernia oil fields — located in a region where oil spills will threaten an already very vulnerable fishery and where the risk of oil spills in rough seas and an “iceberg alley” is perhaps greater than anywhere else in the world. There is striking dissonance here between what is environmentally sensible and what is economically and politically expedient. The environmental movement has brought forward a collection of values that are important to recognize explicitly. These are discussed in the next chapter.



## Chapter 3

### Conceptual Framework

*In an unbelievably short span of time, unplanned and almost mindlessly, our species has become by far the largest factor for change on the planet... Survival of the planet has become of central and immediate concern. (Vancouver Declaration, 1992)*

The health care system faces its greatest challenge in confronting global change in the broad context of “survival of the planet”. To better understand these issues and the directions for action it is useful to explore some concepts that are likely to influence the decisions that must be made. These concepts are environmental health, risk management and sustainable development. It is also important to recognize the role of culture, values and economics when dealing with global change related health issues.

What is needed is a framework that will allow us to deal not only with the health related consequences of global change but also with the underlying causes. While this report makes no claim to providing a definitive framework, it offers some suggestions.

#### Defining Health and Environmental Health

The 1984 WHO definition of *health* is “the extent to which an individual or group is able... to realize aspirations and satisfy needs and... to change or cope with the environment. Health is therefore seen as a resource for everyday life — not the objective of living.” This definition is relevant in the present context.

*Environmental health* means different things to different groups. Health professionals perceive “environmental health” as pertaining to the physical, chemical and biological determinants of human health, such as water quality, air quality, food contamination, toxic hazards. The focus is on human health and how the environment affects it. The major issues have been what causes which effect, how bad is the effect, and how can exposure best be controlled. This paradigm is oriented toward public health practice.

To environmentalists, the focus of the words “environmental health” is on the environmental part. They think more of “the health of the environment”, the integrity of the ecosystem and the protection of the quality of the environment (King, M., 1990). “Ecosystem health” is a suitable term for this. There is a relation to human health insofar as the survival of human society and the quality of human life is affected by destabilization of the ecosystem. These human health effects are usually more indirect, mediated through the food supply, crowding, or chemical influences, or simply cultural anomie resulting from being disconnected from the natural world.

One consequence of these two different interpretations is that public health professionals and environmentalists often find communication frustrating (Guidotti, T.L., 1991). However, progress in addressing many issues identified in this Report requires that better communications be established between these two groups and also with other parties sharing similar interpretations. This requires a clarification of the role of public health in the efforts leading to sustainable development. This question will be discussed later in this chapter.

#### Managing Risk

The conceptual framework of risk assessment and risk management is familiar to all who work in environmental health, by either definition. However, this framework is based on an approach to individual hazards which is itself embedded in a larger framework of how society deals with risks in general. We have now come to a point where major changes may be needed in the way we assess risk. The *Rio Declaration on Environment and Development* has opened the door to such a reassessment by stating that: “Nations shall use the precautionary approach to protect the environment. Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation.” (*Rio Declaration on Environment and Development*, 1992) If applied to health issues, this “precautionary Principle” is likely to have a profound effect on the many established practices.

Human communities all seek to minimize the level of risk from outside aggression, disasters, food shortages, and social isolation. Human institutions exist to protect individuals and society as a whole, and to minimize the level of risk in the community by creating a stable social order, distributing food and other goods, encouraging social interaction, providing opportunities for family formation, and so forth. Thus, controlling risk can be understood as one of the key reasons for an ongoing society’s existence.

One of the most common social mechanisms to control risk has been strengthening the family and extending its reach. However, in the developed world, a high level of risk reduction has been achieved primarily through technology. Residents of North America, western and central Europe, Japan, Australia and other developed areas of the world are living in a cocoon of technologically-controlled risk quite unlike the tenuous living conditions that are the norm in most of the rest of the world and that have been the norm throughout most of human history. It is difficult to imagine how this cocoon could be expanded to include all of humanity when one considers the demands that would result on limited resources and already



stressed ecosystems. However, we cannot deny any large segment of the world's population the opportunity to develop. Since we all live on the same planet, to survive, Western society has little option but to restructure itself on the principle of sustainable development.

This will force an adaptation of technology to confront the realities of sustainable development. In the past, it was always assumed that technology and economic development would be limited by resource availability. It now appears that constraints on economic growth will be imposed instead by the capacity of the environment to absorb the effects of change and human activity.

### **Strategies for Controlling Risk**

There are three levels of strategies for controlling risks to health. Two operate in the context of the first definition of environmental health, involving environmental determinants of human health. The third operates on the level of ecosystem health.

The first strategy is to identify high risk groups and reduce their risk to the general population. This is often the task of occupational medicine and community medicine. These specialties seek to identify and control risk factors, thereby reducing the level of risk in the group to that experienced by the population as a whole.

The second strategy is to change the general level of risk in the population by controlling common exposures and widespread environmental conditions. Public health and, to some degree, the environmental movement have been involved in controlling risk at this level. Often this involves reducing already low levels of cancer risk presented by exposure to low concentrations of chemicals. This may lead to paradoxical situations, when measures that were introduced to lower risk in the past (chlorination of water, preservation of food with chemical additives) are found to be associated with health risks themselves.

The third strategy for controlling risk involves larger-scale ecological issues: global climate change, regional environmental disruption, resource depletion, and population growth.

At this level the risks do not relate to individual risk of experiencing an adverse health outcome, but instead reflect the chances of either gradual or catastrophic disruptions of society or climate or food supply, leading to widespread suffering and social disintegration. Although the risk of disaster is ever-present, especially at the geographical and economic margins of developed society, the most profound health implications are more likely to be indirect, mediated by economic dislocations, population migration, and social stresses.

### **Sustainable Development**

Market-oriented economies provide incentives for the extraction of nonrenewable resources; insufficient penalties for pollution and the consumption of renewable resources in excess of their regenerative capacity; and the extension of trading ar-

eas so far beyond local ecological zones that production and consumption are uncoupled from the carrying capacity of the environment. The cultural costs of such an economic framework include reducing individuals to consumers and replaceable employees and breaking historical and cultural links to the land and natural environment.

The concept of sustainable development is critical to understanding proposals for solutions to the problem of large-scale ecological degradation and resource depletion in the context of personal freedom and the adaptability of markets (Baumol, W.J., 1988; World Commission on Env. and Devel., 1987; Daly, H.E., 1980). It involves establishing an economic structure that consumes only as much as the natural environment produces and emits only as much as the natural environment can absorb. This, it is proposed, will be accomplished in large part through reduced consumption, reduced economic development, recycling and reuse. The economic structure then becomes sustainable in the sense that it can be sustained from one generation to another.

One view is that nothing less than a thorough restructuring of society would accommodate a sustainable economic structure (Lewis, M.W., 1992). Issues of equity and community control over resources and decision-making with respect to their distribution obviously arise. The concept of sustainable development is closely linked, in the minds of many, with that of community empowerment and a host of connected issues related to social justice and cultural expression. The health sector must play a role in defining how our society will move from the current order to a sustainable world.

### **The Way Forward**

Avoiding the adverse health consequences of global change on health will require long-lasting social and cultural change. Through collective action, governments and societies may change the presently destructive course of environmental degradation. The human economic and social systems that depend on environmental exploitation cannot merely be swept aside, but must be replaced by an alternative social order. This social order must be humane, effective in responding to social needs, equitable in the distribution of goods, and historically stable. This means answers for the perennial problems of poverty, development and social justice.

Ultimately, the economic system must shift from a basis of *sustaining* development and production to a basis of *sustainable* development and selective production. This requires that prices be directly related to resource availability and that the true cost of transportation, agriculture, and the distribution of goods be reflected in pricing. In addition, people need sufficient resources, education, and choices to respond to these price changes with reduced demand or the selection of alternatives long before the resource base becomes damaged. Responsibility for environmental reconstruction must be diffused to grass root level — to all people everywhere.



## **The Public Health Response**

Physicians and other health professionals are increasingly concerned about the health implications of issues beyond traditional environmental health — toxic exposures and microbial contamination (Gruppenhoff, J.T., 1990; Guidotti, T.L., 1993). The new point of departure is not individual exposure and the risk of disease, but rather the health implications of ecological changes. Problems such as global climate change and stratospheric ozone depletion do not fit neatly into either the medical model or the population-orientation of public health. Until now, both organized medicine and public health have largely taken a back seat in addressing these issues, leaving them to other scientific disciplines and to environmental activists. That is beginning to change.

Although the public views physicians as credible sources of information on environmental health issues, there are very few physicians who have such training or professional interest. On

a personal level, many physicians are active in environmental groups and concerned about environmental issues, but only a small group of specialists in public health and occupational medicine is now directly involved in the field of environmental health.

Public health is in a position to play a leading role in working toward sustainable development, since its concept of health is broader than that of medicine. There are many activities needed which fall within the expertise of public health physicians: surveillance, monitoring, epidemiological and evaluative studies, public health action and health policy. Surveillance is needed of the distribution and abundance of insect vectors, along with comprehensive reporting of the diseases they cause.

Beyond these traditional activities, public health must engage in creative thinking in terms of sustainable development and must invest in community development and advocate for societal changes that will respond to social needs without destroying the earth.



## Chapter 4

# A Framework for Health Related Research in Canada

With the complexity and interconnectedness of global change in mind, we developed a preliminary Framework for Health Research to guide our thinking. This framework should also be useful in helping researchers and policy makers recognize the dimensions of the field and place global change research within the larger context of environmental health research. Another function of the framework is to help identify research priorities and keep track of new knowledge as it develops.

The framework is an attempt to identify as many as possible of the global change factors that threaten health. We recognize that the framework is incomplete — for instance, it does not go into detail about the interactions of human health and disease with animal and plant health and disease, although these are implied. Nevertheless, we believe it is a useful beginning.

The framework has four categories. The first three are based on threats to human health from three different types of global change. These forms of global change differ from one another conceptually, as well as in the methods of study and the mix of disciplines which might be useful in addressing them. The fourth category acknowledges that human behavioral responses are an important aspect of global change and deserve special attention as a health priority. The definition of each category is followed by *examples* of research activities. These are examples only and not a comprehensive list of research priorities.

Agencies dealing with global change issues may find that the themes of their programs cut across the categories identified here. This is positive: a framework that highlights and juxtaposes significant research categories can also serve to promote connections between categories in a holistic way.

### Category 1: Threats to Human Health from Industrial/Agricultural Pollution

The first category includes threats to human health from society's *production* functions, which release emissions into the environment. Examples of potential threats to human health which fall into this category include: global air pollution ( $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{O}_3$ , motor vehicle emissions); waste disposal of all types (domestic, radioactive, toxics); surface and groundwater contamination and energy production (air pollutants, radioactive wastes, electromagnetic fields).

Studying these threats to health from industrial pollution generally involves traditional methods of study: epidemiology, toxicology, and exposure assessment. But these techniques do need some adaptation to cope with special characteristics, such as widespread "low dose" exposure, the necessity for time

series analysis and the need to understand interactions with physical geographic and climatic variables.

### Category 2: Threats to Human Health from Changes in the Global Environment

In recent years a body of scientific evidence has emerged which suggests that the cumulative impact of human activity is not only changing the global environment through mass action, but also through secondary physicochemical responses throughout the biosphere. An example would be the claim of increased incidence of malignant melanoma in light-skinned populations due to ozone depletion. Claims of this sort are difficult for health researchers to evaluate independently because the starting point of the investigation is the assertion that a secondary change in the global environment is occurring. Health research investigating threats to human health from changes in the global environment will thus need to work closely with scientists from other disciplines who can best judge the validity of such claims and assess the implications of new knowledge as it emerges over time.

At present, some important issues in this category are: the effects of UV radiation on human organ systems and disease outcome (e.g. skin, genetic, immune, eye effects); the relationship between upper atmospheric ozone depletion and increasing UV radiation at ground level; basic science approaches to the impact of global warming on vectors and pathogens (e.g. how will ambient temperature change affect distribution, abundance, life cycles, infectivity?); the relationship of global warming, climate and vegetation change, and respiratory disease; and desertification and the loss of agricultural land.

### Category 3: Threats to Human Health Associated with Levels of Consumption

Complementary to the first category is the concern with global patterns of consumption of non-renewable and photosynthetic resources. In particular, there is the concern that our overall level of consumption is unsustainable. This is based on the idea that if the majority of the world's population were to become as rich as the OECD countries, total consumption of fuel and non-renewable resources would exceed the world's capacity to provide them. Others claim that idea-based innovations will allow us to sustain economic growth while simultaneously controlling or even reducing our levels of consumption of non-renewable and photosynthetic resources.

One example would be the link between urbanization, the development of mega-cities and environmental degradation. What is the relationship between population density and the quality of environments in determining health and well-being in the mega-cities of both the developed and the developing world? Also, what are the health impacts of increased population densities and immigration from low to high consumption regions of the world?

A second example would be the reduction of species



biodiversity. Does the loss of species biodiversity serve as an early warning sign of an underlying global process which will affect human health? Are there more direct effects of reduced species diversity on human health? The typical tropical rainforest is a botanical storehouse of natural organic compounds unanticipated and unstudied by research chemists. Many botanicals have already proven efficacious pharmacologically or have led to synthetic variants with useful properties. How will continuing destruction of the rainforest affect the potential for discovering pharmacologically active compounds in the future? In what other ways will reduced biodiversity adversely affect health?

A third example might be the relationship between the input of global resources in a society and the society's output of healthy life years. It has often been noted that certain third world countries are able to maintain a reasonable health status despite low levels of consumption. This implies a research agenda to identify "healthy" versus "unhealthy" consumption in the high consuming countries.

#### **Category 4: Health Related Human Behavioral Responses to Global Change**

This category acknowledges that human behaviour is pivotal both in terms of how people will react to global change and how they might mobilize to deal with it. More than the other categories, this one will draw upon knowledge about conflict resolution and insights into planned behaviour change developed in the field of health promotion.

Examples in this category would include questions such as the prospects for stimulating changes in values: Can high-consuming regions of the world learn to control their consumption of non-renewable resources? If necessary will we be able to reconsider how we define and value "quality of life"? Changes will likely involve transformations in the type and meaning of work. What do we do about those who will have no future in this transformation? Social dislocations are already associated with resource overutilization and global change, as in the collapse of the Newfoundland cod fishery.

The independence and level of education of women appear to play a decisive role in helping certain low income regions of the world maintain much better health status than would be expected. What are the implications of this phenomenon for health and sustainability globally? How do we effectively communicate valid information about global change to culturally diverse populations around the world?

Another important area in human behaviour related to global change is that of armed conflicts. How is global change related to armed conflicts and the rise of inter-racial/ethnic/cultural violence and extreme forms of nationalism? What will be the social effects of food contamination or destruction due to armed conflicts? What are the mental health implications, risks, stressors and challenges of global change? Behavioural responses can and should help to protect human health at both

the individual and population level, for example by modifying sun-exposure and sun-avoiding behaviour and by public health policies that include provision of shade in school playgrounds and other places where children congregate.

#### **Special Considerations**

The Committee identified four special considerations which would need to be addressed in research projects and initiatives in health-related global change in Canada. They are:

1. The links between research and policy. It would be advantageous to build links between researchers and policy makers into research initiatives. Also, priority ought to be given to initiatives which try to deal with the "research transfer function" in more than a token way.
2. Recognition of the complexity of the underlying issues and solutions. Each of the four categories in the framework above can be construed as beginning with a "forcing function" (i.e. production, consumption, behaviour, and environmental change). They are thus broad causal variables, with complex underlying issues. Addressing these issues will involve multiple consequences and a variety of responses by institutions. For instance, an issue as "simple" as the respiratory effects of motor vehicle emissions raises questions of town planning, urban densification, fuel sources and many more.
3. Focus on Canadian consequences. There should be a focus on Canadian consequences as a subset of global consequences.
4. Attention to Canada's international presence. Attention should be paid to Canada's international presence, especially through IDRC, both in the third world and in polluted areas like Central and Eastern Europe.

#### **Unique Canadian Features Relevant to Global Change and Health**

The Committee recognized that a Canadian program in health-related aspects of global change should give priority to special Canadian features relevant to the subject. In particular:

1. Canada has a large, environmentally and culturally sensitive Arctic region.
2. Canada contains a large share of the world's fresh water.
3. Canada has one of the world's highest levels of resource consumption per capita, especially in the energy field, and is one of the world's highest emitters, per capita, of atmospheric air pollutants.
4. Canada is one of the world's most multicultural societies, which represents, collectively a formidable degree of expertise in comprehending global issues.
5. Many salient aspects of global change are reflected in the phenomenon of high rates of immigration to Canada, from



the immediate (e.g. importation of “exotic” diseases) to the long-term (e.g. the impact of massive population transfers from low consuming to high consuming regions of the world).

6. Canada’s health care system may come under increasing stress as a result of adverse health outcomes from global change. Will its unique features lead to a model response or will the infrastructure collapse?

### Canadian Strengths

The Committee was able to identify several areas in which Canadian investigators had demonstrated special strength relevant to health related global change. These are areas in which Canada might play a leading role internationally. They are shown in Table 3.

### Areas for Improvement in Canada

The Committee also identified problem areas which need to be addressed in order for greater progress to take place. Several

of these problem areas may be addressed by new initiatives at the federal level, but will require ongoing vigilance in order to ensure that weakness is turned to strength.

1. Longitudinal data bases: Despite our strength in record linkage we have few national population samples being followed longitudinally. This reduces our opportunities for monitoring the determinants of health over time. The National Population Health Survey will not, at first, make a priority of issues related to global change, but may include relevant items later. There are also problems of piecemeal databases, and problems of jurisdiction.
2. Inadequate links between the social sciences, natural and health sciences: This is a priority of the tri-council Eco-research Fund, but has not yet been extended into programs related to global change. Moreover, there is reason to believe that current programs have produced a lot of multidisciplinary proposals but not very much interdisciplinary thinking.
3. Inadequate training of health care workers in handling the cultural barriers facing immigrants.

**Table 3. Leading roles for Canada in the international arena**

- ▶ The epidemiology of melanoma, especially related to environmental risks
- ▶ Effects of environmental pollution in Great Lakes ecosystem
- ▶ Biomedical and environmental ethics
- ▶ Molecular genetics, both human and plant
- ▶ Immunology
- ▶ Neurosciences
- ▶ Transcultural psychiatry
- ▶ Immigrant and refugee studies
- ▶ Medical anthropology
- ▶ Psychology of social change
- ▶ Universal health care, health record systems and health record linkage technology
- ▶ Crop improvements, especially grains and oilseeds



## Chapter 5

### Global Change Research: Priorities and Implementation

#### Priority Setting

Setting priorities involves comparing and ranking competing items. They may be ranked in order of importance, relevance, public interest, intellectual appeal, political significance, impact on health, or a variety of other factors, or combinations of them. One of the first key questions is whose values and interests are being reflected in the priorities.

The necessity of considering whose values and interests are being represented can be illustrated from two recent books on methods of setting health research priorities: *Establishing Health Priorities in the Developing World* (Walsh, J.A., 1988) prepared by Julia Walsh for the United Nations Development Programme (UNDP) and *Research Strategies for Health* (Davies, M.A., 1992), prepared by the Advisory Committee on Health Research (ACHR) of the WHO. Both these documents reflect the opinion that research priorities should be based on the impact of health problems on infant, child and maternal health, but add that health problems which sap the vitality of men who make up the working population (e.g. AIDS), thus having significant economic impact, also have high priority. By implication, health problems that affect predominantly the elderly (cancer, heart disease, stroke, senile dementia) have lower priority in the developing world.

This priority setting focuses on human health, neglecting ecosystem health, which has great relevance for the human condition. King has stressed the relationship of health to sustainable development: if health research is aimed predominantly towards infant, maternal and child survival, population growth can outstrip the capacity of local and regional ecosystems to sustain

the population (King, M., 1990). This is the demographic trap. People must then migrate or starve, or fight to achieve sustainability (an option reflected by the many wars in developing countries since the end of World War II).

#### The Importance of Surveillance and Trend Assessment

In attempting to set priorities, we have to define the scope of what needs to be ranked. In addition to original research, other information is needed that is not currently available. Much of this comes under the general heading of surveillance and trend assessment. For example, surveillance might include measurements of UV flux in relation to stratospheric ozone levels, which can then be related to epidemiologic trends in skin cancer and cataract. Routine epidemiologic surveillance can also alert us to unusual outbreaks of infectious disease that might be due to impaired immunity or to the introduction of exotic pathogens. Other trends worth monitoring would include the numbers and distribution of insect vectors of disease and the pathogens they carry, and their relation to ambient temperature and humidity levels; the incidence and prevalence of respiratory diseases in relation to ambient levels of environmental pollutants and allergens; cancer incidence and human reproductive outcomes in relation to levels of many kinds of environmental contaminants.

#### Defining Research Priorities

The Health Issues Panel identified the priorities for surveillance and trend assessment shown in Table 4. We identified

**Table 4. CGCP Health Issues Panel priorities**

|                                          |                                                                                                                                                  |                            |                                                             |
|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-------------------------------------------------------------|
| <b>Surveillance and trend assessment</b> | UV flux in relation to ozone layer composition                                                                                                   | <b>Surveys</b>             | Behaviour, attitudes towards sun exposure                   |
|                                          | Incidence rates:<br>melanoma<br>non-melanoma skin cancer<br>cataract<br>respiratory diseases<br>cancer<br>birth defects<br>reproductive outcomes | <b>Evaluative studies</b>  | Sunscreens and other protective measures<br>Health messages |
|                                          | Monitoring of<br>acute sun exposure effects<br>acute heat-wave effects                                                                           | <b>Biomedical research</b> | Effects on human health of reduced biodiversity             |



several obvious areas for health research: the efficacy of sun-screen protective creams and ointments, identification and evaluation of effective ways of delivering health messages about sun-avoiding behaviour, the relationship of reduced biodiversity and human disease, and how human values influence behaviour. However, recognizing that our limited expertise might lead to bias, we felt that we should have additional input from others. We therefore sought ideas from a wide range of health scientists and other opinion-leaders across Canada.

We circulated two open-ended questionnaires to approximately 200 research administrators, deans of health professional institutions, chief executive officers of national professional associations, and research workers across Canada, as well as several experts in other countries. The first mailing included the Framework outlined above. Open-ended questions were then asked on which topics should be highest priority for research, and on Canada's existing and potential research strengths. Following receipt of responses to the first questionnaire, a meeting was held with representatives of the Medical Research Council (MRC), Social Sciences and Humanities Research Council (SSHRC), National Research Council (NRC), International Development Research Centre (IDRC) and the Health Protection Branch of Health Canada. At this meeting, barriers to new research initiatives were identified. The most significant barrier was that most of the departments or agencies who could potentially be involved in funding global change research have funds earmarked in such a way as to make it difficult to fund.

For example, the focus of the Tri-Council Eco-research program is primarily on Canadian ecosystems, not on global change; thus currently available research funds are earmarked for Eco-research. At Health Canada, priorities may be consonant with those we have identified, but no funds are available to create new partnerships with the university community. IDRC's research priorities are also consonant with our Panel's, but IDRC supports research in developing countries, not in Canada. Thus in the second questionnaire we were particularly interested in identifying barriers which might exist to developing strong interdisciplinary research programs and suggestions for solutions.

We received 60 responses to the first set of questions, and 31 responses to the second. Results of the first set of questions are shown in Tables 5 and 6. Table 5 shows the overall highest priorities, based on each respondent's ranking of his/her five highest priorities. Pollution-related research, including air pollution, water pollution, global warming and ozone depletion, was mentioned 68 times. Studies oriented towards aspects of behaviour, including changes in human values, women's health, cultural factors in relation to communicating information, were mentioned 50 times. Population-related research, including issues such as urbanization, crowding and migration was in the priority lists 38 times.

**Table 5. Opinions about highest priorities**

|                                           |    |
|-------------------------------------------|----|
| <b>Population-related:</b>                | 38 |
| Urbanization, growth, migration, crowding |    |
| <b>Pollution-related:</b>                 | 68 |
| Air pollution, water pollution            | 32 |
| Global warming                            | 19 |
| Ozone depletion                           | 17 |
| <b>Behavioural:</b>                       | 50 |
| Stimulating value changes                 |    |
| Women's health                            |    |
| Birth control                             |    |

Table 6 shows that air pollution ranks very high, but this may be due to variation in understanding of the term. Many respondents seem to have included greenhouse gas accumulation in this term. Human behavioral research also received high priority. This is also a broad topic with different connotations. Some interpret it as specific health-related behaviour such as sun-seeking and sun-avoidance, others as reproductive behaviour (attitudes towards family size), and yet others as conservation or environmental ethics.

**Table 6. Highest priorities within each topic**

|                      |                                                                                                                                                                                                                                      |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Pollution</b>     | Global air pollution<br>Waste disposal<br>Water contamination<br>Energy production                                                                                                                                                   |
| <b>Global change</b> | Global warming effects on vectors, pathogens<br>Global warming effects on climate, vegetation, respiratory disease<br>Global warming effects on food production<br>Ozone depletion<br>Effects of UV radiation on human organ systems |
| <b>Consumption</b>   | Urbanization, population density, migration<br>Groundwater depletion<br>Reduced biodiversity                                                                                                                                         |
| <b>Behaviour</b>     | (How to) stimulate changes in values/behaviour<br>Women's health and reproductive behaviour<br>Social dislocations                                                                                                                   |



Most respondents believe that new research initiatives would require the input of epidemiologists, toxicologists and a wide range of social and behavioral scientists. There was agreement that we do not need to recruit and train new cadres of research workers or to invest in expensive new resources or equipment, but rather we need to reorient existing research resources and begin a multidisciplinary collaborative approach, or intersectoral collaboration. New coalitions must be built and multidisciplinary approaches encouraged.

## Implementing the Priorities: Barriers and Solutions

Based on the results of this questionnaire, which indicated that innovative interdisciplinary approaches were required, we sent a second questionnaire, focussing on implementation, to the same individuals. We were particularly interested in identifying barriers to developing strong interdisciplinary research programs. We requested written responses to questions on how Canada should establish the capacity for interdisciplinary research in health aspects of global change and on the suitability of current structures, and suggestions for improvement. The answers are summarized below.

*Q1. How should Canada go about establishing the capacity for interdisciplinary research in the health aspects of global change?*

The answers to this question can be grouped into seven broad themes: 1) top-down organization of research; 2) international participation; 3) the role of Canadian funding agencies; 4) communication; 5) the need for an integrated health information system and exploitation of existing data bases; 6) wider participation of the private contract research sector and the service sector; and 7) concentration on specific areas (population control, preventive technologies, establishing venture capital funds for new technology). The first four themes were addressed by the largest numbers of respondents and so will be elaborated in more detail.

- 1) *"Top-down" organization of interdisciplinary research.* Strong support was expressed for a top-down, national strategic planning process to facilitate interdisciplinary research. This would involve identifying priorities, relevant disciplines and existing teams, and then screening prospective individuals and teams for excellence, commitment, and the ability to share and collaborate. Several team models were also suggested, all involving some sort of core funding and serious, enlightened, periodic evaluation. The models included the EPRI (Electric Power Research Institute), the Canadian Institute for Advance Research (CIAR) Population Health Program, the McMaster University/University of Toronto Institute of Environment and Health and the National Centres of Excellence Program.
- 2) *International participation.* It was suggested that Canada's national research priorities on health-related global change

should be developed in consultation with IDRC and other international agencies. In particular, Canada should carve out areas where its researchers have special strengths. Ultimately, funding should come from a mixture of national and international sources.

- 3) *The role of Canadian funding agencies.* There was strong support for strengthening the existing Tri-council (MRC, SSHRC, NSERC) eco-research initiative, so that it could be extended to issues of Global Change. Several respondents who did not know about the existing Tri-council initiative invented it on paper in response to this question. In addition to calls for more money, respondents suggested that infrastructure funding be strengthened; that guidelines be established for interdisciplinary research; that interdisciplinary training be increased; and that ways be found to help interested researchers take risks in this field without jeopardizing existing funding.
- 4) *Communication.* There were calls for more communication between managers of research funds and between relevant disciplines. Suggestions were made about how to accomplish this: interdisciplinary conferences, a Royal Society of Canada sponsored discussion group, a formal information network, a government-sponsored interdisciplinary journal, and a program of interdisciplinary sabbaticals and work programs. Improving communication could start with wide circulation of this report throughout academia.

There were two dissenting voices. One expressed doubts about whether interdisciplinary research really works. The second questioned whether the quality and value of research is correlated with the number of disciplines involved. This person proposed that Canada not establish separate structures to fund interdisciplinary research, since such structures would lend themselves to "crass opportunism and shot-gun weddings that would not survive the honeymoon."

*Q2. In general, are existing research structures and funding procedures conducive to interdisciplinary research in the health aspects related to global change?*

Only eight people responded with a "yes" to this question; 22 answered "no"; three voted "yes and no" and four did not give a categorical response. This question had three sub-questions:

*Q2a. If not, how can they be made more responsive? Please identify the problem(s) and suggest improvements.*

The problem most frequently identified by the respondents related to the role of existing research funding agencies. In particular, the current vertical organization of research councils leads to funding single-disciplinary research and to preference for applications from certain types of departments. If biomedicine is not the prime topic or if research methods do not follow epidemiologic concepts of causality, MRC and NHRDP (National Health Research and Development Program) usually won't fund. Moreover, the perceived underfunding of



existing research makes expansion into new areas difficult. It is also hard to fund outside (i.e. interdisciplinary) consultants from existing grant programs.

Another barrier to interdisciplinary research lies in the differences among specialties. There are different technical languages, methods and research substrates, which can be hard to bring together successfully. A third barrier concerned human behavioral issues. There is a common peer review ethos that researchers who move from their discipline base into interdisciplinary work are “jumping around”. Researchers are inhibited by the fear of looking bad among their peers and potential collaborators. It was also suggested that some interdisciplinary research networks are hampered by parochial concerns and ego. The Canadian Institute for Advanced Research (CIAR) was referred to as a model which had got beyond these concerns.

A societal dimension was also mentioned. Although environmental awareness has increased among the public, the public is still not alarmed enough about global change concerns to generate a strong lobbying effort (like AIDS, breast cancer). This kind of strong lobbying is needed for there to be a significant effect on research priorities and funding. Moreover, it was suggested that government agencies and departments do not know about the activities of related agencies and so cannot provide leadership for interdisciplinary initiatives.

When it came to suggesting improvements, the respondents were divided almost evenly between those who made proposals to improve the existing granting agencies' performance in this area and those who proposed the creation of a new agency. Ways to improve existing agencies included having other councils learn from model programs (the SSHRC competition in Applied Ethics, the NSERC strategic grants program); creating new funding categories at the MRC and NHRDP; shifting funding from MRC to NHRDP; supporting MRC's new “vision B” process; creating new Networks of Excellence; and providing more funding for outside consultant collaboration. Two respondents felt that existing agencies would be able to meet the challenges if they were better educated about health-related global change issues.

Respondents who felt that we need a new agency were looking for more radical changes. They were looking for the development of a broad conceptual framework that could bring medical, social, behavioral, and physical scientists together, a strategic priority-setting process and new evaluation procedures and protocols for research funding.

There were additional suggestions independent of agency arrangements. Granting agencies need to foster openness to new ideas even if they do not fit existing practices. They also need to trust the judgements of experienced researchers who enter new, risky areas in mid-career, so that there will not be a disincentive based on concerns for maintaining core funding. Symposia and workshops could help get the ball rolling. The rest of the suggestions came from single respondents only. These

included: creating focus groups to develop approaches to certain priority problems, emphasizing contracts over investigator-driven work, giving a leadership role to existing cooperative research groups, making sure that researchers have advisory input into research program development, and giving access to research funds to centres outside the mainstream medical-academic ones.

Q2b. *At Universities and Research Institutes, are research workers' promotion, tenure and salary conducive to interdisciplinary research initiatives?*

Two-thirds of the respondents thought not. Although there may be considerable variation based on the views of the department chairperson and the practices of the promotion and tenure committee, there are many important institutional barriers. The “publish or perish” doctrine encourages people to stick to safe topics and to short term research which can yield quick publications. Journal reputation matters at tenure time, and most of the prestigious journals are not dedicated to interdisciplinary work. The amount of research funding may create incentives to submit low risk proposals in core disciplines. Moreover, joint-appointed and cross-appointed faculty are often distrusted, and “brownie point” incentives for interdisciplinary work are often ineffective. Finally, university budgets based on programs are hard to rearrange. The departments then become adversaries to the transfer of funds to interdisciplinary groups.

One could conclude from the above that nothing short of a cultural revolution in Canadian science would do the trick, and this was suggested. Although some felt that this would be very difficult at the present time, when research funding is shrinking and the pressure to teach rather than do research is increasing, others saw optimism in the present situation. One respondent suggested that declining research funding was pushing people to consider interdisciplinary research efforts. Another thought that recognition of complex problems was beginning to emerge in Canadian science in a way which would lead to greater interdisciplinary activity. Finally, one respondent believed that there had been real progress recently in bridging the gap between biomedical science and other forms of human health study.

Those who felt that conditions *are* conducive to interdisciplinary research were generally referring to their own working situations. Such positive situations exist at the NRC, University of Waterloo and Guelph, where the commitment is built into the mandate of the institution right from the beginning.

Q2c. *What efforts need to be made to attract students (undergraduate, graduate) to interdisciplinary research projects?*

The attitude of the respondents was summed up by the respondent who wrote:

“Students need to know that interdisciplinary research projects...



- give them access to the best scientists;
- give them access to well-funded research projects;
- will provide options for future significant research;
- will provide postgraduate and postdoctoral opportunities;
- will provide employment options;
- are considered valuable to Canadians in that the research is recognized as contributing to current significant issues or problems;
- are fun!"

At least one-third of the respondents suggested that the availability of personal and project funding, by itself, would generate lots of students. So would evidence of job opportunities and secure career pathways. Role models of successful interdisciplinary researchers and teams were another key ingredient. It would be easy to attract students if teaching faculty were

involved in successful teams and were dealing effectively with the personality issues that come up in team research.

Several respondents suggested that high quality problem-based teaching methods, at both the graduate and undergraduate level, will convince students of the value of interdisciplinary education. Others felt that at the undergraduate level a strong background in a single discipline is important and that interdisciplinary studies should start at the graduate level. There was agreement, though, that we need to overcome the perception that interdisciplinary students are getting a superficial education in each contributing discipline. This means having the universities give more status to interdisciplinary programs, and having the programs ensure that they are not providing a superficial education.

The need for special arrangements for interdisciplinary students was a recurrent theme; the most common suggestion being the availability of an interdisciplinary PhD program on campus.



## Chapter 6

### Conclusions and Recommendations

We have described the widespread and mainly harmful changes that can be expected to affect the environment and human health, as a result of the interconnected phenomena of global change. By any standards, these amount to a massive public health problem.

Historical precedent informs us that to control public health problems, several things are needed:

- Awareness that the problem exists
- Understanding of its causes
- Capability to deal with the problem
- Political will to take action to control the problem

These four actions in combination have, over the past century and a half, led to successful control of fecal-oral and respiratory infectious diseases that took a heavy toll of life in the urbanizing societies of the early industrial world. Since the middle of the 20th century, as awareness, understanding, capability and political will have all increased, we have seen some successes in reducing the toll from cardiovascular diseases, notably coronary heart disease and the toll of premature death due to tobacco addiction, and of traffic crashes associated with alcohol-impaired driving.

Discussing the above sequence, and especially the fourth and perhaps most essential step, political will, Vickers (Vickers, G., 1958) used the phrase, “Redefining the unacceptable.” Thus, for example, in the late 19th and early 20th century it became unacceptable in western industrial cities to dispose of human waste by dumping it in city streets or in rivers that were used to supply drinking water, and unacceptable to cough and spit in places of public assembly. Laws and regulations reinforced the social sanctions against such actions. Since the middle of the 20th century, it has become socially unacceptable to smoke cigarettes during public meetings, in confined spaces such as elevators and public transport, and in most workplaces; again this progressively increasing social unacceptability has been reinforced by laws and regulations.

What is needed now is a vigorous campaign by medical scientists, health professionals, practising physicians and public health specialists, to build momentum towards achieving these four essential steps to control the present and potential health problems attributable to global change. The scientific community is aware of the problems described as global change; so, to a large extent, is the general public. There is fairly widespread comprehension of the causes. In this instance, our capability to deal with the problem depends in large measure on our ability to change our behaviour — in the phrase coined by the World Health Organization, to “Think globally, act locally.”

What is missing is the political will to act. In short, we must redefine as unacceptable some industrial, commercial and personal behaviours that are now widespread. For instance, we must redefine as unacceptable the custom of commuting to and from work in a car carrying just the driver.

This leads to the first of our enabling recommendations.

#### Enabling Recommendations

**Recommendation 1.** Efforts should be undertaken to ensure that all members of the biomedical science community and all practising health professionals in clinical and public health practice be made aware of the importance of health related issues associated with global environmental changes and of the actions needed to minimize the impact of global change.

**Recommendation 2.** Governments in Canada and other developed countries should allocate a minimal proportion (e.g. 5%) of their health budgets to knowledge development and knowledge transfer for the prevention of diseases and health promotion. Within this envelope, research on global health issues should be given high priority.

**Recommendation 3.** Canada should take a lead role in facilitating the development and conduct of a long-term international cooperative health research program.

Global change and the related human health issues are of great concern to Canada and other developed and developing countries. It is clear that research on the wide range of health issues will be difficult and expensive. The international community, particularly the developed countries which must finance the bulk of such research, needs to reach consensus on the needs and priorities for health research related to global change. Research methods should be standardized internationally so that results from various countries can be compared and assessed.

**Recommendation 4.** Canada should develop model structures that can be used as prototypes for the conduct of multidisciplinary long-term research. Funding agencies should provide infrastructure and incentives for the conduct of difficult, long-term research related to global change by establishing financial envelopes, flexible guidelines, broad-based peer review panels and career scientist awards for persons involved in multidisciplinary global health research. Canada should promote these model structures both in Canada and through international health agencies.

**Recommendation 5.** The Canadian health research community should communicate to decision-makers the importance of global change issues to the future health of Canadians and the world.



**Recommendation 6.** Canada should foster communication between health researchers on global health issues in Canada and internationally by financially supporting a spectrum of international links such as electronic networks, meetings for project development and scientific conferences.

**Recommendation 7.** Canada should establish surveillance systems to assess trends in population exposures and disease risks related to global change.

## Research Recommendations

**Recommendation 8.** The Need for a National Centre of Excellence

**Recommendation 8.1.** The Research Councils, in collaboration with Federal and Provincial Governments (Ministries of Education, Science, Health) should establish a National Centre of Excellence, for multidisciplinary studies of the health impacts of global change, ways to ameliorate the adverse effects of global change, and ways to minimize the adverse effects of unavoidable global change.

**Recommendation 8.2.** The CGCP should urge the Research Councils and other funding agencies to encourage and financially support research on health impacts of global change, with maximum emphasis on innovative interdisciplinary studies.

**Recommendation 9.** Threats to Human Health from Industrial/Agricultural Pollution.

**Recommendation 9.1.** The acute and chronic effects of global air pollution on human health should be assessed through population-based epidemiologic studies. Priorities include improved disease surveillance systems and risk assessment of the effects of global air pollution on susceptible groups such as the very young, the elderly and persons with cardiorespiratory diseases.

**Recommendation 9.2.** The role of chronic exposure to toxic contaminants in drinking water (e.g. adverse pregnancy outcome events and cancer) should be assessed through prospective epidemiologic studies with sufficient size and reliable exposure measures to permit detection of relatively weak effects.

**Recommendation 9.3.** Research into more effective waste management and water treatment methods is needed to reduce or eliminate toxic contaminants in drinking water.

**Recommendation 10.** Threats to Health from Changes in the Global Environment

**Recommendation 10.1.** There is an urgent need for research into use of scientific information in political decision making so that health policies for the prevention of the disastrous predictable effects of global warming will be adopted world wide.

**Recommendation 10.2.** There is a need for agricultural research on heat and drought resistant crops, pest control and food storage under adverse conditions.

**Recommendation 10.3.** There is an urgent need for health surveillance systems to assess trends and regional differences in ground-level ultraviolet light intensity and the relation of these to (i) atmospheric ozone levels, and, (ii) skin cancer incidence rates (especially melanoma). There is an immediate opportunity for Canada to facilitate such research through the International Agency for Research on Cancer (IARC). Canada belongs to IARC and this agency is developing a protocol for this issue. However, there is a need for Canadian cancer registries and public health agencies to improve data collection on the incidence, staging and outcome of skin cancers.

**Recommendation 10.4.** Research on knowledge, attitudes and behaviours is needed to develop and evaluate programs to reduce the risk of adverse health effects of sun exposure.

**Recommendation 10.5.** Epidemiologic research to assess the relative importance of sunscreens and other preventive behaviours and early detection of skin cancer, respectively, in reducing the risk and case fatality rates of skin cancer is needed. Canada has expertise for biomedical research on the role of ultraviolet light in cataracts, immune suppression and chronic nonmalignant skin changes; epidemiologic research is needed to complement the biomedical research.

**Recommendation 11.** Threats to Human Health associated with Current and Future Patterns and Levels of Consumption

**Recommendation 11.1.** Research on contraception for men and women, particularly methods acceptable in developing countries, should be assigned very high priority for Canada.

**Recommendation 11.2.** Research on groundwater conservation is needed to prevent or reduce the health effects directly attributable to water shortage.

**Recommendation 11.3.** Research on the relation between human health and biodiversity is needed (e.g. vector distribution and spread of Lyme disease).

**Recommendation 12.** Health-related Human Behavioral Responses to Global Change.

**Recommendation 12.1.** Broadly based research on human values and the environment is needed to address fundamental issues which underlie global change (e.g. how to encourage reduced consumption while preserving levels of well-being).

**Recommendation 12.2.** Research is needed to develop policies and methods to mitigate the population migration and social dislocation that would follow severe global



change (e.g. health problems related to diseases and health-related behaviours prevalent in the country of origin).

**Recommendation 12.3.** Research on health education and independence for women is needed to promote family planning in Canada and other countries with diverse cultures and economies.

## Public Health Policy and Action Recommendations

**Recommendation 13.** Public health action should include advisory messages about sun exposure, standard-setting and advice on protective clothing and health education directed at behaviour change.

**Recommendation 14.** Health workers should advocate for national leaders to take action to limit the burden of greenhouse gases.

**Recommendation 15.** Public health should play an active role in health promotion, disease prevention and health care of migrant populations.

**Recommendation 16.** As weather disturbances become more violent, mass movement of environmental refugees may occur. Public health services should prepare for such disasters.

**Recommendation 17.** Public health professionals should provide input at the policy level and promote the development of national food and nutrition policies in keeping with sustainable development.



## **Conclusion**

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The Warning to Humanity, issued in 1993 by the Union of Concerned Scientists, spelled out the grave damage suffered by the environment as a consequence of uncontrolled population growth and unrestrained exploitation of all aspects of the global environment, and outlined immediate remedial action: control all environmentally damaging activities, restore and protect the earth's life support systems, manage resources more effectively, stabilize the population, and reduce inequalities. This Warning is a very powerful statement, suggesting several high priority research themes, especially in the area of health-related behaviour. There is a sense both among Panel members

and among respondents to our questions, that this is the highest research priority.

There is wide agreement on the nature and importance of health problems attributable to global change. Much of the needed research expertise to study and resolve these problems already exists in Canada. The Research Councils should recognize the high priority of global change research related to human health and should encourage research proposals in this area. There is a good argument in favour of establishing at least one national centre of excellence dedicated to health-related global change research.



## List of Key Acronyms and Abbreviations

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|       |                                                  |                 |                                                       |
|-------|--------------------------------------------------|-----------------|-------------------------------------------------------|
| ACHR  | Advisory Committee on Health Research            | nm              | Nanometer ( $10^{-9}$ meter)                          |
| AIDS  | Acquired Immune Deficiency Syndrome              | NO <sub>x</sub> | Nitrogen Oxides                                       |
| CFCs  | Chlorofluorocarbons                              | NRC             | National Research Council                             |
| CGCP  | Canadian Global Change Program                   | O <sub>3</sub>  | Ozone Molecule                                        |
| CIAR  | Canadian Institute for Advanced Research         | OECD            | Organization for Economic Cooperation and Development |
| DNA   | Desoxyribonucleic Acid                           | PCBs            | Polychlorinated Biphenyls                             |
| EPRI  | Electric Power Research Institute                | SO <sub>2</sub> | Sulfur Dioxide                                        |
| IARC  | International Agency for Research on Cancer      | SSHRC           | Social Sciences and Humanities Research Council       |
| ICSU  | International Council of Scientific Unions       | UNDP            | United Nations Development Programme                  |
| IDRC  | International Development Research Centre        | UNEP            | United Nations Environmental Program                  |
| IPCC  | Intergovernmental Panel on Climate Change        | UV              | Ultraviolet                                           |
| MRC   | Medical Research Council                         | UV-A            | 320-400 nm Ultraviolet Wavelength Interval            |
| NASA  | National Aeronautics and Space Administration    | UV-B            | 280-320 nm Ultraviolet Wavelength Interval            |
| NHRDP | National Health Research and Development Program | UV-C            | 200-280 nm Ultraviolet Wavelength Interval            |







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